Gaze aversion during social interaction in preterm infants: a function of attention skills?

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Abstract

Preterm infants avert their gaze more often and for longer periods in early social interactions compared to full term infants. In previous studies this finding is interpreted as being a function of the higher degree of parental stimulation that is often found in parents of preterm children. The current study explores an additional hypothesis. Since the development of general visual attention abilities is found to be less optimal in preterm children, it is possible that less optimal maturation of attention abilities partially explains the elevated gaze aversion in a social context. Therefore, the current study investigated the association between gaze aversion in a social context and the ability to disengage and shift visual attention in a non-social context in 20 preterm and 42 full term infants aged 4 and 6 months. Results confirm that preterm infants are slower to shift their attention in a non-social context and that they avert their gaze more often in a social context compared to full term children. Furthermore, more frequent gaze aversion during social interaction at 6 months was related to longer disengagement and the shifting of attention at 4 and 6 months, but only within the preterm group. The results suggest that attention maturation is less optimal in preterm children; this can be observed in a non-social as well as a social context. Less attention maturation in preterm children can negatively influence the amount of time they can stay actively involved in social interaction.

Keywords: prematurity – social interaction – gaze aversion – attention regulation - infancy

1. Introduction

From birth onwards, infants are sensitive to eye gaze directed at them. They tend to visually orient to the parent's eyes and face – in general: the human's face – what is an important social marker as it is interpreted as the propensity of the infant to connect to another human (Farroni, Csibra, Simion, & Johnson, 2002; Rochat & Striano, 1999). In the first weeks after birth, periods of gazing towards the parent's face are rather scarce, partially due to the fact that the attainment of an alert state is difficult (Colombo, 2001). Around the post term age of 6 weeks, alongside the appearance of social smiling, periods of gazing at the parent's face become more extended (Rochat & Striano, 1999; Trevarthen, 1979). Around that age, when the parent initiates an interaction and captures the attention of the young infant, it is frequently described that the attention of the infant will be 'hooked' on the parent (Brazelton, Koslowski, & Main, 1974), which is also referred to as obligatory looking (Stechler & Latz, 1966), reflecting the infant's difficulty in disengaging from something or someone once engaged with it.

When the ability to disengage and shift attention develops between 2 and 6 months (Colombo, 2001; Matsuzawa & Shimojo, 1997), visual attention in a social context changes markedly. In addition to orienting towards the person's face, infants will show increasing interest in the environment by orienting and visually exploring objects surrounding them. It has frequently been observed that, from at least three months onwards, the duration of time a child spends gazing towards a person's face during face-to-face interaction decreases in favor of an increase in time spent orienting on objects in the environment (Feldman, 2007a; Kaye & Fogel, 1980; van Beek, Hopkins, & Hoeksma, 1994). It is hypothesized that this latter development is a function of increased maturation of the visual attention network (Johnson, Posner, & Rothbart, 1991), but it can be assumed that it will also be a function of the ability of the interaction partner to maintain the interest of the child towards him or her and a function of the tendency of the interaction partner to stimulate the infant's exploration of the environment.

Detailed observation of social interaction between infant and parent has revealed that these interactions are characterized by rhythmic cycles of attention and non-attention in the infant (Brazelton et al., 1974), or "on" and "off" (Stern, 1974). These authors hypothesized that periods of withdrawal are important for infants in order to limit the visual input and/ or in order to process information. Socially, periods of non-attention are interpreted as periods of time during which a child socially withdraws. Such periods of withdrawal become a topic of concern when they are found to a greater degree in children relative to what is 'normally' expected.

Various studies have reported that, after preterm birth, the withdrawal seems to be more pronounced, as periods of gazing away are longer and seem to occur more frequently in preterm children compared to full term children (Feldman, 2007b; Field, 1977; 1981; Goldberg & DiVitto, 2002; Landry, 1986). Preterm birth is generally related to a less optimal development (Allen, 2008; Woodward et al., 2009). Studies have investigated the early parent-infant interaction in preterm children, not only because of the fact that this interaction can play a mediating role for further development (Sameroff & MacKenzie, 2003), but also because it can be assumed that the medical assistance the child needs and the early separation between parent and the immature child will interfere with the co-construction of the parent-child relationship.

The finding that preterm children show less attention behavior which indicates social orienting and social involvement has led researchers to investigate its association with social-related factors, especially with maternal behavior (Feldman, 2007b; Field, 1977; Goldberg & DiVitto, 2002). The psychological impact of the preterm transition to parenthood and the stress it all evokes can lead to lower parental sensitivity and to more controlling behavior towards the child (Muller-Nix et al., 2004). This behavior can negatively influence the social involvement of preterm children (Field, 1977). At the same time, less social involvement in a child can lead parents to take a more active and less sensitive stance, so the relationship between parent and child will clearly be bidirectional. However, without wanting to minimize the importance of this bidirectionality in social interactions between preterm children and their parents, it is important to bear in mind that the preterm child brings certain characteristics into the interaction that are possibly not specific to the social context which can lead to the difficulties preterm infants have in maintaining attention in a social context, regardless of parental behavior.

It is well documented that preterm children are at risk of a less optimal maturation of general visual attention functions, measured in a non-social context, although age is corrected for prematurity in most of the infancy studies (van der Weijer-Bergsma, Wijnroks, & Jongmans, 2008, for a review). This less optimal development shows deficit persistence up to childhood (Rose, Feldman, & Jankowski, 2009), and early attention processes in preterm infants are related to parent-reported symptoms of attention deficit hyperactivity disorder later in life (Lawson & Ruff, 2004), which is diagnosed in a higher proportion of children born preterm compared to full term (Johnson et al., 2010).

Regardless of context, visual attention is a broad multi-functional domain characterized by major developmental changes in infancy (Colombo, 2001). The goal of the current study was not to try to capture this broad domain, as only one function of general visual attention was measured, namely the ability to disengage and shift attention. This ability is part of the visual orienting network (Posner & Petersen, 1990) that develops strongly in the first six months of life (Colombo, 2001) and which shows less optimal development after preterm birth. Until a few weeks after expected birth, studies report the opposite, as early accelerated maturation of the visual orienting network in preterm infants has been found, possibly due to the early extra-uterine experience and early visual stimulation that preterm infants experience compared to full term infants (Butcher, Kalverboer, Geuze, & Stremmelaar, 2002; Hunnius, Geuze, Zweens, & Bos, 2008). However, it is important to recognize that this more favorable reaction around expected birth does not remain (Hunnius et al., 2008). Studies report that, towards the post term age of 5-6 months, preterm infants show longer look durations, are slower to disengage and shift attention and show lower shift rates between stimuli compared to full term infants (Butcher et al., 2002; Rose et al., 2001; 2009), what is indicative for less mature visual orienting behavior.

The current study investigated the hypothesis that elevated gaze aversion of preterm children in a social context partially reflects more general attention problems in these children. To investigate this, we associated gaze aversion in a social context with the ability to disengage and shift attention in a non-social context in preterm and full term infants at 4 and 6 months, with age corrected for prematurity.

Firstly, it was explored if we could replicate the finding that preterm infants gaze away more often and longer than full term infants in social dyadic interaction (Field, 1977; 1981; Goldberg & DiVitto, 2002; Landry, 1986). It is important to emphasize that periods of gazing away did not include periods of time in which children were orienting towards objects in the environment, similar to van Beek, Hopkins, and Hoeksma (1994), in addition to the exclusion of the periods of time infants were gazing at their mother. Other studies have operationalized periods of gazing away as those periods during which infants were not engaged in eye contact with the mother (Field, 1977; Malatesta, Grigoryev, Lamb, Abin, & Culver, 1986). However, as mentioned earlier, with increasing age, it was expected that infants would also orient towards objects in the environment, and this behavior reflects increased maturation of the visual orienting system and is therefore not suitable to be included in the category of gaze aversion. Therefore, the first goal was to explore if preterm infants would still show elevated gaze aversion if orienting towards objects in the environment surrounding the mother was excluded.

Secondly, we investigated disengagement and the shifting of attention with the noncompetition/competition paradigm based on Frick, Colombo, and Saxon (1999) using eye tracking technology. The noncompetition/competition paradigm consists of several trials starting with a stimulus that is presented on the centre of a screen to which the visual attention of the child is attracted. Then, in half of the trials, a peripheral stimulus appears on the screen while the central stimulus remains visible (i.e., competition condition). In the other half of the trials, the central stimulus disappears simultaneously with the appearance of the peripheral stimulus (i.e., noncompetition condition). The variable of interest is how long it takes infants to visually ‘reach’ the peripheral target. It was expected that infants would perform more quickly in the noncompetition condition than in the competition condition, as it is assumed that the latter condition demands infants to additionally disengage from the central stimulus, whereas the former does not. Furthermore, it was expected that there would be developmental growth between 4 and 6 months (Matsuzawa & Shimojo, 1997), so that infants would become quicker with maturity. This growth was especially expected in the competition condition, as previous research has shown that the ability to disengage shows marked improvement between 4 and 6 months (Matsuzawa & Shimojo, 1997). It was hypothesized that preterm infants would be slower to disengage and shift their attention than full term children.

Finally, it was investigated whether elevated gaze aversion in preterm infants was related to less mature orienting abilities to disengage and shift attention. It was hypothesized that elevated gaze aversion in preterm children was partially an expression of a broader attention problem, rather than being solely a reflection of a social attention problem.

2. Method

2.1. Participants

In this study, 20 preterm infants and 42 full term infants aged 4 and 6 months, with age corrected for prematurity, participated with their parents. All infants were firstborns. Preterm infants were recruited via the Neonatal Intensive Care Unit (NICU) of Ghent University Hospital and the full term infants were recruited via Child and Family, a local primary health service. Infants with a gestational age between 28 and 34 weeks were included, so extremely preterm and late preterm born children were excluded. Infants were also excluded if they were diagnosed with severe intraventricular haemorrhage (grade III/ IV), periventricular leukomalacia, or with a severe sensory impairment (i.e., retinopathy of prematurity stage 3/4 and/ or an abnormal Algo test). Table 1 shows the medical characteristics of the preterm sample. Seven preterm children were twins, of whom only the first-borns were included in the study. Due to the specific inclusion criteria and due to cooperation with only one NICU, we had a small sample from which we could recruit the preterm children. This caused the different group sizes (20 preterms and 42 full terms).

<Insert Table 1 about here>

The full term infants were born after a normal pregnancy, with a gestational age between 38 and 42 weeks, and a delivery without severe complications for child or mother. Physical examination of the infants at birth was normal.

Parents received a letter at home between 2 and 6 weeks after the discharge of their child from the NICU (preterm) or hospital (full term) informing them about the study. If they were willing to participate, they were asked to send some personal information (name of child, gestational age, and telephone number), to which the investigator responded by making telephone contact with the family. In both the preterm and full term groups one third of the families participated.

Demographic characteristics of the preterm and full term sample can be found in Table 2. The social-economic status (SES) was based on the Hollingshead index (Hollingshead, 1975). There was no difference between preterm and full term children in mean SES, $t(60) = -.70$, *ns.* Most infants were living in middle to high SES families.

<Insert Table 2 about here>

2.2. Procedure

Visual attention was assessed at 4 and 6 months. Infants were examined within seven days before or after these ages at home. Parents received a small gift at 4 months and 30 euro at 6 months for the participation of their family in this study.

The procedure was similar at the two ages and consisted of a standardized infant-mother interaction and a noncompetition/competition task on a computer screen. The order of the two tasks was counterbalanced between children (not within children) in order to be able to control for order effects. No order effects were found, so this variable will not be discussed in the Results section.

Each visit started with an informal talk about the process of the research and the development of the child in order to put parents at ease and to obtain general information about the child. The standardized infant-mother interaction and the noncompetition/competition task were administered at a place at home where visual distraction was minimal (e.g., a corner of the living room) and it was ensured that no highly salient features (toys, lights) were present within 90° left or right of the infant (reference 0-point was the point when infants looked straight ahead when seated in their chair).

2.2.1. Standardized infant-mother interaction. The infant was seated in a commercial seat and the mother was asked to interact with her child for 3 minutes. She was free to interact with her infant as usual, with the exception that she was not allowed to use toys or to touch her infant in order to ensure that interactions did not greatly differ in the amount of stimulation infants would receive. The interaction started when the infant was judged to be relaxed and alert and the infant was not allowed to have a pacifier. If the child started crying during the interaction, the child was first calmed down, and the interaction was started again afterwards. The interaction was recorded with two cameras; one focused on the child's face and another camera recorded both mother and infant. These two recordings were afterwards combined into a split-screen recording to improve the coding process.

2.2.2. Noncompetition/competition paradigm (based on Frick et al., 1999). Infants were seated in a commercial seat at a distance of approximately 65 cm from a 17" monitor on which stimuli were presented. The Tobii T60 Eye Tracker (Tobii Technology, Sweden) was integrated into this monitor. Eye tracking technology was used to accurately record visual fixations of the infants with regard to the screen. The T60 Eye Tracker is a non-invasive and invisible technique used to administer eye movements and therefore does not affect the performance of the infants. The additional advantage of the T60 eye tracker above other eye tracking devices is that it is less sensitive for head movements, which is especially important in research with infants. The data rate of the Tobii T60 Eye Tracker is 60 Hz, corresponding with a collection of raw eye movement data points every 16.7 milliseconds.

The T60 monitor (monitor A) was connected to a portable monitor (monitor B). The examiner supervised the experiment on monitor B, which was set-up behind the child. On monitor B, the examiner saw the vision that was presented to the child at monitor A. Additionally, the child's fixation points and saccades were plotted with a red dot or a red line respectively on monitor B in real time. This 'live viewer' function made it possible for the examiner to see where the child was looking precisely at that moment.

Before recording began, a calibration process was conducted. The stimulus was a vibrating colourfully drawn animal making funny sounds. The attractiveness of the stimulus is very important in the calibration process in order to optimize the chance that the infants will fixate exactly on the stimulus. The stimulus was firstly presented on the top right of the screen. If it was clear that the child fixated on it, a key was pressed by the researcher. Thereafter, the stimulus was presented successively on the other three corners of the screen and in the middle of the screen. If the calibration process was successful, the noncompetition/competition task began.

The stimuli that were presented to the infants on a black screen during the task were rectangles with a visual angle of 6° (horizontal) by 17° (vertical) containing a highly contrasting white-black checkerboard surrounded by a yellow or red frame. The central stimulus did not differ from the peripheral stimulus. The central stimulus was presented in the middle of the screen. The peripheral target was presented at the right or left with a horizontal spatial gap of 6° away from the central stimulus.

The noncompetition/competition procedure consisted of 16 trials. Each trial began with a gentle sound of 500 ms, after which a central target appeared on the screen. When the child fixated on this central target for 1 second, a key was pressed by the examiner. At that moment, a peripheral target appeared on the screen. In half of the trials ($N = 8$) the central stimulus remained on the screen when the peripheral target appeared, i.e. the competition condition. In the other half of the trials ($N = 8$), the central stimulus disappeared simultaneously with the appearance of the peripheral stimulus, i.e. the noncompetition condition. The trial stopped when the child fixated on the peripheral target or looked away from the screen; if the child kept on fixating the central stimulus, the trial was stopped after 10 seconds (but this did not happen at 4, nor at 6 months). The trial was stopped by a key press causing the return to a stimulus-free black screen. The inter-trial interval was 1.5 seconds, after which a new trial began, starting with a gentle sound lasting for 0.5 seconds.

At the start of the procedure, and each time after four trials, a little bird appeared at the centre of the screen singing and moving, in order to direct the attention of the infants to the screen if necessary. The trials differed in condition (competition versus non-competition), lateral position (right versus left) and colour of the frame (yellow versus red). There were two trials for each combination (e.g., competition - left - yellow). The order of the different combinations was random, although it was ensured that no more than two consecutive trials were presented in the same position (left - right) or with the same condition (competition - non-competition).

Failed trials were not re-assessed in children. Based on Frick et al. (1999) it was expected that keeping children longer in the testing situation would worsen the infants' performance due to fatigue or fussiness or enhance their performance due to increased familiarity with the task. If a child started fussing or crying during the procedure, the infant was calmed down, after which the procedure was continued.

2.3. Behavioral measures

2.3.1. Standardized mother-infant interaction. Three different codes were possible. If children gazed towards the direction of their mother's face it was coded as *gazing at mother*. *Orienting* was coded if the infant was clearly looking at his/her own hands or feet, at the hands of the mother, at objects that were part of the set-up (e.g., camera's, chair strap) or at other objects. Based on the category of focused attention of Lawson and Ruff (2004), it was explained to the coders that this orienting behavior is characterized with an intent facial expression and often accompanied by reduced vocal and motor activity. *Looking away* was coded when infants gazed away from their mother's face and when they were not orienting towards something in the environment. This category included briefly looking away during an interaction, (slightly) closing the eyes, looking away accompanied by arching of the back, turning of the body, or increased motor activity.

Two observers who were blind to the perinatal risk and background of the children coded all the observations in Observer 8.0 (Noldus). Coding was performed at half-speed. The two observers were intensively trained until their interrater reliability was good (intraclass correlation above .80). Thereafter, they coded all the interactions. At the end, 10% of the interactions were double coded to compute interrater reliability. Intraclass correlations were good: For gazing at mother's face, *ICC* = .99, for orienting, *ICC* = .92, and for looking away, *ICC* = .84.

2.3.2. Disengagement paradigm. The variable of interest was the time to first fixation on the peripheral stimulus (i.e., the area of interest). To obtain this variable, firstly, all recordings were visually controlled via the replay function in Tobii software. Only trials where the fixation of the child on the central target moved directly to the peripheral target were included. Thus, the following trials were excluded: (1) trials in which the child blinked, (2) trials during which the eye gaze of the child was not captured well by the eye tracker causing a small interruption during which the direction of regard was not clear, and (3) trials in which the child looked away or looked in the wrong direction. In addition to this, trials in which the reaction time was faster than 150 milliseconds were excluded (as in Rose, Feldman, Jankowski, & Caro, 2002), as these fast reaction times are thought to be anticipatory eye movements.

2.4. Missing data

All infants participated at 4 and 6 months; however, the dataset was not complete (see further in this section). When data are missing, the question always arises regarding how to deal with this outcome. Children who have missing data are by default excluded from analyses (i.e., listwise deletion). However, Schafer and Graham (2002) point out that this is not a good way to deal with missing data and describe maximum likelihood (ML) or Bayesian multiple imputation as 'the state of the art' *if* data are missing (completely) at random. Via this method, missing cells in the data set are replaced, which leads to more reliable results and improved power.

For the mother-infant interaction, data were missing for two full term infants at 4 months, due to infant fatigue and due to the inability to revisit these families within the timeframe of a few days. It can be assumed that the reason for these missing data is completely random.

For the noncompetition/competition task, data were missing for infants at 4 months (preterms, n = 5; full terms, n = 5) and at 6 months (preterms, n = 1; full terms, n = 1). In addition, data were missing for two full term infants at both 4 as well as 6 months. At 4 months, all the missing data (with the exception of the two full term infants at 4 months that were too sleepy) in the noncompetition/competition task were due to the impossibility of reliably tracking the eyes of the children. One important causal factor was the difficulty in keeping the head of the 4-month-old infants in the right position relative to the screen. It can be assumed that these data are missing completely at random, as the reason for the missing data (i.e., motor development) has nothing to do with the variables of interest. At 6 months, however, motor problems were never an issue. The reason for the missing data at that age was that the children were not able to keep their attention on the screen. For these children, we can hardly assume that the data were missing at random. Therefore, the missing data at 6 months were not imputed, neither were the missing data for the two full term children who had no data at either time point.

The Expectation-Maximization (EM) algorithm (Dempster, Laird, & Rubin, 1977), available in SPSS, an iterative imputation method computing ML estimates (Schafer & Graham, 2002), was used to impute the missing data at 4 months. Thus, eventually, the dataset contained data for the infant-mother interaction at 4 and 6 months, N = 62, for the noncompetition/competition task at 4 months, $N = 60$ and for the noncompetition/competition task at 6 months, $N = 58$.

3. Results

3.1. Preliminary analyses

3.1.1. Noncompetition/ competition task. Firstly, the data were controlled for univariate outliers. There was no evidence for outliers within a child, which would have been reflected by a time to first fixation on a trial of more than 3 *SD* above or below the child's own mean. One full term child at 6 months was an outlier (> 3 *SD*) compared to the full term group mean at that age. This child was, however, not excluded from the analyses, as this problem was solved by a log transformation of the data. This transformation was necessary, as the raw data showed substantial positive skewness (Tabachnick & Fidell, 2007).

3.1.2. Social (dyadic) interaction. No univariate outliers, controlled for within groups and ages, were found. The data of three variables (orienting at 4 months and looking away at 4 and 6 months) showed moderate skewness and were transformed with a square root transformation (Tabachnick & Fidell, 2007).

3.1.3. Descriptive statistics. Analyses were conducted with the transformed variables (with the exception of the Repeated Measures Analysis of Variance for orienting, as only orienting at 4 months and not orienting at 6 months was transformed), but for reasons of clarity, the descriptive statistics are based on the raw data. Table 3 shows the descriptive statistics of the observed variables separately for the full term (M_{ft}, SD_{ft}) and preterm (M_{pt}, SD_{pt}) groups.

The variables reflecting visual attention in the social contexts (variables 1 to 6) are presented in percentage duration of time. The variables reflecting time to first fixation on the peripheral stimulus are presented in milliseconds. Additionally, the table presents the correlations between the variables within the two tasks. Most important are the correlations over time. For the social interaction, a positive correlation was found between the two ages for look away behavior. Furthermore, more orienting behavior at 4 months was related to less look away behavior at 6 months. No other significant correlations over time were found. For the noncompetition/ competition task, a marginal positive correlation was found between the two ages for time to first fixation in the competition condition. No significant correlation was found for the noncompetition condition over time. <Insert Table 3 about here>

3.2. Visual attention in a social dyadic interaction

Repeated Measures Analyses of Variance were conducted to examine the age and group effects on visual attention in a social context. Age (4 and 6 months) was entered as a within-subject variable, and group (preterm and full term) was entered as a between-subjects variable. The percentage of time that infants looked away, gazed at the mother and oriented were the variables of interest. Because the number of times (frequency) infants looked away is meaningful in the context of attention problems, this variable was also part of the analyses. Consequently, we could investigate the hypothesis that preterm children looked away longer *and* more frequently than full term children. No analyses are reported with the number of times (frequency) of gazing at the mother's face and orienting to the environment because these variables are not of importance regarding our research questions.

3.2.1. Look away – duration. The results yielded a significant age main effect, $F(1, 60) = 5.76$, $p < .05$, and group main effect, $F(1, 60) = 9.60$, $p < .01$. No significant age x group interaction, $F < 1$, was found. Infants looked away longer at 4 months than at 6 months, and preterm infants looked away longer than full term infants at both ages.

3.2.2. Look away – frequency. The results yielded a significant age main effect, $F(1, 60) = 5.02$, $p < .05$, a significant group main effect, $F(1, 60) = 4.34$, $p < .05$, but no significant age x group interaction effect, $F < 1$. Infants looked away more frequently at 4 months ($M =$

8.58, *SD* = 6.95) than at 6 months (*M* = 6.60, *SD* = 5.14), and preterm infants (*M* = 9.48, *SD* = 5.48) looked away more frequently than full term infants (*M* = 6.69, *SD* = 4.64).

3.2.3. Gazing at mother. The analyses yielded a significant age main effect, $F(1, 60) = 19.16$, $p < .01$, and a marginally group main effect, $F(1, 60) = 3.65$, $p < .10$. No significant age x group interaction was found, $F < 1$. Infants gazed at their mother's face les frequently from 4 months to 6 months. Preterm infants gazed slightly less at their mother's face than full term infants.

3.2.4. Orienting. An age main effect was found, $F(1, 60) = 36.60$, $p < .01$. No group main effect, $F < 1$, nor significant age x group interaction, $F < 1$, was found. Infants oriented more at 6 months than at 4 months.

3.3. Visual attention in a noncompetition / competition task

A Repeated Measures Analysis of Variance was conducted. Age (4 and 6 months) and condition (noncompetition and competition) were entered as within-subject variables, and group (preterm and full term) was entered as a between-subjects variable. Time to first fixation to the peripheral target was used as a dependent variable.

A significant age main effect, $F(1, 56) = 9.43$, $p < .01$, condition main effect, $F(1, 56) = 8.58$, $p < .01$, and group main effect, $F(1, 56) = 5.62$, $p < .05$, were found. In addition, an age x condition interaction, $F(1, 56) = 7.12$, $p < .01$, and a marginally significant age x group interaction, $F(1, 56) = 3.50$, $p < .10$, was found. No condition x group, no age x group and no three-way interaction (for all, $F < 1$) was found.

Infants' time to first fixation on the peripheral target was longer in the competition condition than in the noncompetition condition, and decreased from 4 to 6 months. However, this decrease was especially true in the competition condition. The time to first fixation in the noncompetition condition stayed fairly stable from 4 to 6 months. This resulted in the finding that no significant difference was found at 6 months of age between the two conditions.

Preterm infants were slower to shift their gaze towards the peripheral target than full term infants in both conditions. However, this group effect was only found at 4 months and disappeared at 6 months.

3.4. Correlation between visual attention in both tasks

In this final part, it was investigated whether the higher duration and the greater frequency of looking away behavior in the preterm group during social interaction were related to the attention capacities of these infants, more specifically, to disengagement and shifting of attention.

As bivariate correlations are susceptible to bivariate ouliers, Mahalanobis Distance (MD) was computed for each pair of variables. The highest MD-score was 6.67, which does not come close to the critical values proposed by Barnett and Lewis (1978, as cited in Field, 2009) for bivariate correlations. Some exploratory analyses which excluded the children producing the highest MD-values did not significantly change the correlation values, yielding additional evidence that the significant correlations were not influenced by one case.

There were several correlational differences between the preterm and full term group, as investigated with Fisher's r to z transformation. Therefore, it was not appropriate to present the correlations for the whole group. The correlations for the preterm and full term group are therefore presented separately in Table 4.

3.4.1. Preterm infants. Preterm infants who gazed away from the interaction *more frequently* at 6 months, were *slower* to disengage their attention from one stimulus to shift attention towards another stimulus at 4 as well as 6 months. Similarly (but only marginally related), the *longer* infants looked away from the social interaction at 6 months, the *slower* they were in the competition condition at 6 months. The correlation between the duration of looking away behavior at 6 months and the competition condition at 4 months ($r = .370$) did not reach significance, probably due to the small sample size.

Looking away at 4 months was not related to the time to first fixation in the noncompetition and competition condition at 4 and/or 6 months. Furthermore, time to first fixation in the noncompetition condition was not related to looking away behavior in social interaction.

<Insert Table 4 about here>

3.4.2. Full term infants. There was one significant, but negative, correlation between the noncompetition condition at 6 months and the duration of looking away during social interaction at 6 months, such that full term infants who were faster to reach the peripheral target in the noncompetition condition at 6 months looked away longer at 6 months. Additionally, but only marginally significantly related to each other, the longer it took full term infants to reach the peripheral target at 6 months in the competition condition, the more frequently and longer they looked away at 6 months.

4. Discussion

The rationale of this study was previous findings that preterm infants show more gaze aversion than full term infants in a social context (Field, 1977; 1981; Goldberg & DiVitto, 2002; Landry, 1986) and simultaneously show a less optimal development of attention abilities (van der Weijer-Bergsma et al., 2008). The first goal of this study was to replicate these group differences using a more stringent operationalization of look away behavior in the social context and by using eye tracking technology to more accurately measure attention processes in a non-social context. The second goal was to investigate whether an association could be found between visual attention in a social and non-social context.

Firstly, results confirmed the expected group differences. Preterm children showed more and longer periods of looking away at 4 and 6 months. Importantly, these periods did not include the instances in which the infants were visually orienting to other objects in the environment (van Beek et al., 1994). Thus, the elevated gaze aversion from the mother's face in preterm infants is not due to elevated orienting behavior, but is due to more unoriented look away behavior in these children. For all children, the duration of time infants oriented towards objects in the environment increased with growing age, whereas the duration of gazing towards the mother's face decreased (as in van Beek et al., 1994). The duration of time infants were gazing away also decreased from 4 to 6 months. Concerning the stability of the measures, the results gave evidence for some short-term stability from 4 to 6 months for look away behavior. Gazing at the mother and orienting towards the environment showed no stability over time. As we previously noted, the amount of time infants spend gazing towards their mother or orienting towards the environment depends on different factors such as the effort the mother makes to try to maintain the interest of the child directed at her and the tendency of the mother to stimulate the infant's exploration of the environment. For us, gazing at the mother, as well as orienting towards the environment, indicates both positive infant attention and involvement. This is in contrast with look away behaviour, which is elevated in preterm children and seems indicative of less mature processes (Field, 1981). The data show that this look away behavior displays at least short-time stability between 4 and 6 months. The data also indicate that if infants show more orienting behavior at 4 months, they will show less look away behavior at 6 months.

In the noncompetition/competition condition, preterm infants were slower in both conditions at 4 months. This group difference had disappeared at 6 months. This is in contrast to Butcher et al. (2002) who found preterm infants to become slower than full term infants towards 6 months. This difference could partially be due to procedural differences. For example, the spatial gap between the central and peripheral target was only 6° in our study, where it was approximately 25° in the study of Butcher et al. (2002), placing higher demands on the saccades (Garbutt, Harwood, & Harris, 2006). There was no evidence that preterm infants were slower to disengage, as they did not perform worse than full term infants in the competition compared to the noncompetition condition (i.e., no group x condition interaction). Concerning age differences, infants became faster from 4 to 6 months in the competition/noncompetition task, but especially in the condition that demanded disengagement (i.e., competition condition), confirming previous findings that disengagement becomes faster between those ages (Butcher et al., 2002; Matsuzawa & Shimojo, 1997). Concerning the stability of the measures, the data showed a marginal positive correlation between 4 and 6 months for the time to first fixation in the competition condition, but not in the noncompetition condition.

Secondly, the results give support for significant correlations between attention behavior in a social and non-social context. Preterm infants who were averting their gaze more often at 6 months were slower to disengage and shift attention (i.e., competition condition) at 4 and 6 months. To a lesser degree, the same conclusion was reached for the duration of looking away at 6 months. This seems to suggest that elevated gaze aversion is partially related to less mature attention skills in preterm children. This finding is in congruence with the hypothesis of Field (1981), which states that the elevated gaze aversion in preterm infants may be due to less well-developed information processing abilities compared to full term children. Field’s hypothesis was based on the finding that preterm children showed more gaze aversion than full term children, even when the amount of stimulation the children received was controlled for, suggesting that preterm children possibly need longer and more frequent gaze aversion to process the same amount of information. Our data cannot fully confirm this hypothesis, as our attention measure was not designed to assess information processing abilities (Blaga & Colombo, 2006), although visual attention is assumed to be one part of information processing (Rose et al., 2009).

Although these results support our initial hypotheses, other results are more difficult to interpret. Firstly, correlations between visual attention in a social and non-social context were different for the full term group compared to the preterm group. The most important difference was that the (marginally) significant correlations were all negative instead of positive; the faster the full term children were in the noncompetition condition (and to a lesser degree in the competition condition), the longer they looked away. It seems that the hypothesis we made for the preterm children is not suitable for full term children. In line with our study, a negative correlation has also been reported in full term children by Abelkop and Frick (2003), who found that full term children who were able to quickly disengage and shift attention between stimuli, were are also more capable of disengaging and looking away from the interaction partner as a strategy to deal with a socially distressing situation. The finding that the correlations between look away behavior and disengagement of attention are in the opposite direction for the preterm group compared to the full term group can be indicative for a curvilinear U-shape curve. It is highly probable that a moderate level of look away behavior is optimally achieved and that this moderate level is related to more mature visual attention processes. Periods of look away behavior are indeed necessary in order to limit and process the amount of information an infant (more generally, a person) receives (Brazelton et al., 1974; Doherty-Sneddon & Phelps, 2005; Stern, 1974). In the population of healthy full term children, we can expect that more look away behavior is related to more mature (disengagement and) shifting of attention (i.e., the left side of the U-shape curve). This is in line with the findings of Abelkop and Frick (2003) and with our findings in the full term group. However, if an at-risk group becomes a concern because of elevated levels of look away behavior, we can no longer expect that more look away behavior indicates more mature visual attention. On the contrary, we expected an association between longer/ more look away behavior and more time needed to disengage and shift attention (i.e., the right side of the U-shape curve) for the preterm group. The data confirmed this hypothesis.

A second finding related to the previous one is that, for preterm children, look away behavior is related to the competition condition, whereas, for full term children, look away behavior is related to both the competition as well as the noncompetition condition. The results for the preterm children are in line with previous studies (Landry, Smith, Miller-Loncar, & Swank, 1997, 1998) suggesting that the (difficulties with) disengagement of attention in preterm children may negatively influence the visual attention of these children in a social context. For the full term children, the correlation between look away behavior and the competition condition is in line with Abelkop and Frick (2003), but the significant negative correlation between the noncompetition condition and look away behavior at 6 months for the full term group was not anticipated. It seems that more look away behavior in the social context is related to the ability of children to quickly disengage and shift their attention, rather than being solely a function of the maturation of the disengagement function. Again, it shows that gaze aversion will not mean the same thing for preterm children compared to full term children.

A last notable finding is that whereas look away behavior at 6 months was related to the (non-)competition conditions, look away behavior at 4 months was not. It is always puzzling when some correlations are valid for one age, but not another age. As this is one of the first studies to investigate the correlation between visual attention in a social and non-social context, more insight is needed into this domain in order to be able to explain this finding. It is, however, typical for follow-up studies that correlations are sometimes age-specific (e.g. Bee et al., 1982; Mundy et al., 2007).

Some important remarks should be noted. Firstly, the assumption that the more quickly infants can disengage and shift to something, the more mature their attention processes are, is also suggested in other studies (Butcher et. al, 2002; Frick et al., 1999; Hunnius et al., 2008; Rose et al., 2001, 2009). This may be the case, but fast disengagement and quick shifts between stimuli can also be indicative of attention problems, as it can indicate that infants are less engaged with the stimulus (van der Geest, Kemner, Camfferman, Verbaten, & van Engeland, 2001). So, the appropriateness of fast disengagement and shifting will need further investigation.

Secondly, a limitation of the current study is that no extensive battery of attention abilities was administered. Given the fact that young infants' time in alert states is still limited, it was decided that several paradigms on a computer screen on top of the assessment of the social interaction would be too much for infants aged 4 and 6 months. The ability to disengage and shift attention was chosen as this skill undergoes important development between those ages, a development that seems to be less optimal in preterm children (Butcher et al., 2002; Matsuzawa & Shimojo, 1997).

A last remark is that, although more look away behavior was related to slower disengagement and shifting of attention in the preterm group, the correlations were only moderate; this suggests that other factors such as maternal behavior will be important in explaining variance in gaze aversion. Also, the finding that group differences diminished between 4 and 6 months in the non-social context, but not in the social context, illustrates this.

In conclusion, the current study gives evidence that preterm children avert gaze more often in a social context and are slower to shift attention compared to full term infants at 4 months. The difference in the social context remains until at least 6 months, but diminishes in the non-social context. Slower shifting and disengagement of attention at 4 and 6 months was related to elevated gaze aversion in a social context in preterm children at 6 months. This finding can further augment our understanding of social visual attention in preterm children. Elevated gaze aversion has previously been related to social behavior of the caregiver, as it is a logical step to search in a social context for processes that can explain this phenomenon, especially because literature shows that preterm birth can affect the mother-infant interaction (Goldberg & DiVitto, 2002). If the elevated gaze aversion is pronounced, caregivers also tend to search for causes in their own. Although the social context will be an important factor that is associated with elevated gaze aversion, the current study also suggests that general visual attention abilities should be taken into account when seeking to understand elevated gaze aversion in preterm children.

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Table 1. *Medical characteristics of the preterm sample (N = 20)*

	M	*SD*
Birth weight (g)	1 551.41	406.01
Gestational age (weeks)	30.93	1.37
Apgar score 1 min	6.22	2.18
Apgar score 5 min	7.83	1.29
Time on respirator (days)	1.67	2.74
Time on oxygen (days)	13.67	25.19
Hospitalization (days)	48.56	18.28
	N	*%*
Small for gestational age[a]	2	10
Respiratory distress syndrome		
Grade I/II	9	45
Grade III/IV	-	-
Intraventricular haemmorhage (grade I/II)	-	-

Note. [a]Birth weight below 10% of the population mean for a given gestational age.

Table 2: *Demographic characteristics of the preterm and full term sample*

	Preterm (*N* = 20)		Full term (*N* = 42)	
Male / female, *N*	10 / 10		22 / 20	
SES, *M* (*SD*)	40.55	(9.79)	42.85	(11.11)
Maternal age (years) , *M* (*SD*)	31.97	(5.21)	29.30	(3.57)
Age[a] (days), *M* (*SD*)				
4 months	123.35	(3.42)	121.95	(3.45)
6 months	182.94	(3.44)	182.81	(3.91)

[a] Age corrected for prematurity.